WIDEBAND MEASUREMENTS AND ANALYSIS OF PROPAGATION LOSSES WITHIN A BUILDING

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ABSTRACT

An simplified setup using an HP network analyzer to perform path loss measurements for the indoor radio channel in the 0.8 - 1 GHz band is described. In order to analyse the frequency selectivity of the channel, two new postprocessing data methods are proposed. A comparison with another published method is also presented.

INTRODUCTION

Indoor radio propagation has been an active area of study in recent years, with several reporting wideband impulse response measurements. Radio propagation studies can be performed either in the time domain or in the frequency domain. The advantages of the frequency domain measurements were pointed out in Reference [1]. However, there is another advantage that has not yet been used: the possibility to analyse the selectivity of the transmission channel. This paper describes a simplified version of the configuration initially proposed by Pahlavan and Howard [1] and also improved by Zaghloul, Morrisson and Fatouche [3]. Though the setup proposed here is similar to that of Zaghloul *et al.*, the method of operation and analyses presents some particularities.

MEASUREMENT SETUP

The main component of the measurement system is an HP 8753C network analyzer with an HP 85046A S-parameter kit that outputs a swept frequency signal and analyses the received signal. The signal generated by the network analyzer is propagated by a $\lambda/4$ omnidirectional antenna with a gain G=0 dBi. The output of the network analyzer is connected to the transmitting antenna through a 50 m coaxial cable with 8 dB attenuation at 0.9 GHz. The signal from the similary receiver antenna is returned through a 4.5 m coaxial cable to the network analyzer to determine S_{21}. The transmitting and receiving antennas are wideband units with groundplane, placed at 1.5 m.

Concerning the time invariance of the channel, the measurements were collected during the summer hollidays, when all the universitary campus of INSA-Rennes was deserted. No other researchers were in the LCST laboratory. The surrounding environment was also kept stationary by preventing movements. This allows us to assume that the channel was time invariant during the measurements.

In order to reduce the influence of the noise, for each position of the transmitting antenna, four measurements were performed and the results were averaged.

The calibration of this instrumentation was performed out the 50 m coaxial cable. So, the measured channel is represented by the building and the two antennas with their coaxial cables.

DESCRIPTION OF THE MEASUREMENTS

The measurements were spatially distributed throughout the test area (the ground flour of the LCST laboratory) by fixing the receiving antenna in a corner of a laboratory and moving the transmitting antenna to different locations. During the measurements, the both antennas were kept fixed.

The measurements consist of 801 values for $|S_{21}|$ at a frequency spacing of 0.25 MHz for a frequency span of 200 MHz, which is centered at 0.9 GHz. The magnitude of S_{21} is obtained in LOGM format and represents the power loss of the channel. For each location were obtained 801 magnitude values. The power of the signal generated by the network analyzer is +20 dBm (the maximal value) and the sweep time for the four measurements is 650 ms.

MEASUREMENT ANALYSIS

The main objective of this measurements is to determine the radio coverage, that is related to the power-distance relationship in the area.

A. *Averaged power loss versus distance:* For a fixed transmitter power and a fixed frequency, the power loss (P) increases with distance (d) between antennas as:

$$P(f,d) = A(f)\, d^{\alpha(f)} \qquad (1)$$

where $\alpha(f)$ is the exponent of the power-distance relationship and $A(f)$ is the power loss for d = 1 m. In Reference [1], a simple analysis is described, using averaged values for $P(f,d)$:

$$P(d) = E[P(f,d)] = \frac{1}{801}\sum_{i=1}^{801} P(f_i,d) \qquad (2)$$

where:

$$f_i = 800 + (i - 1)\, 0.25\ [\text{MHz}]\,, \quad 1 \le i \le 801 \qquad (3)$$

As in Reference [1], assuming that:

$$P(d) = A\, d^{\alpha} \qquad (4)$$

when the logarithm of (4) is taken, the linear relationship:

$$10 \log_{10} [P(d)] = 10 \log_{10} (A) + \alpha\, [10 \log_{10} (d)] \qquad (5)$$

between power loss in dB and 10 $\log_{10}$ of the distance results. Using a linear regression analysis [4], the minimum mean square error (MMSE) line is calculated for the dependence of power loss (dB) on 10 $\log_{10}$ of the distance. The slope of the regression line gives the experimental value o α.

The linear regression analysis gives $\alpha = 1.925$ and A = 36.7 dB. The standard deviation of the average power losses from the regression estimates is erms = 2.35 dB. The correlation coefficient $r = 0.933$ indicates that increasing power loss is highly correlated with increasing distance.

B. *Power loss versus distance for each frequency:* The results presented above represent global values. When the logarithm of (1) is taken, the relationship:

$$10 \log_{10} [P(f,d)] = 10 \log_{10} [A(f)] + \alpha(f)\, [10 \log_{10} (d)] \qquad (6)$$

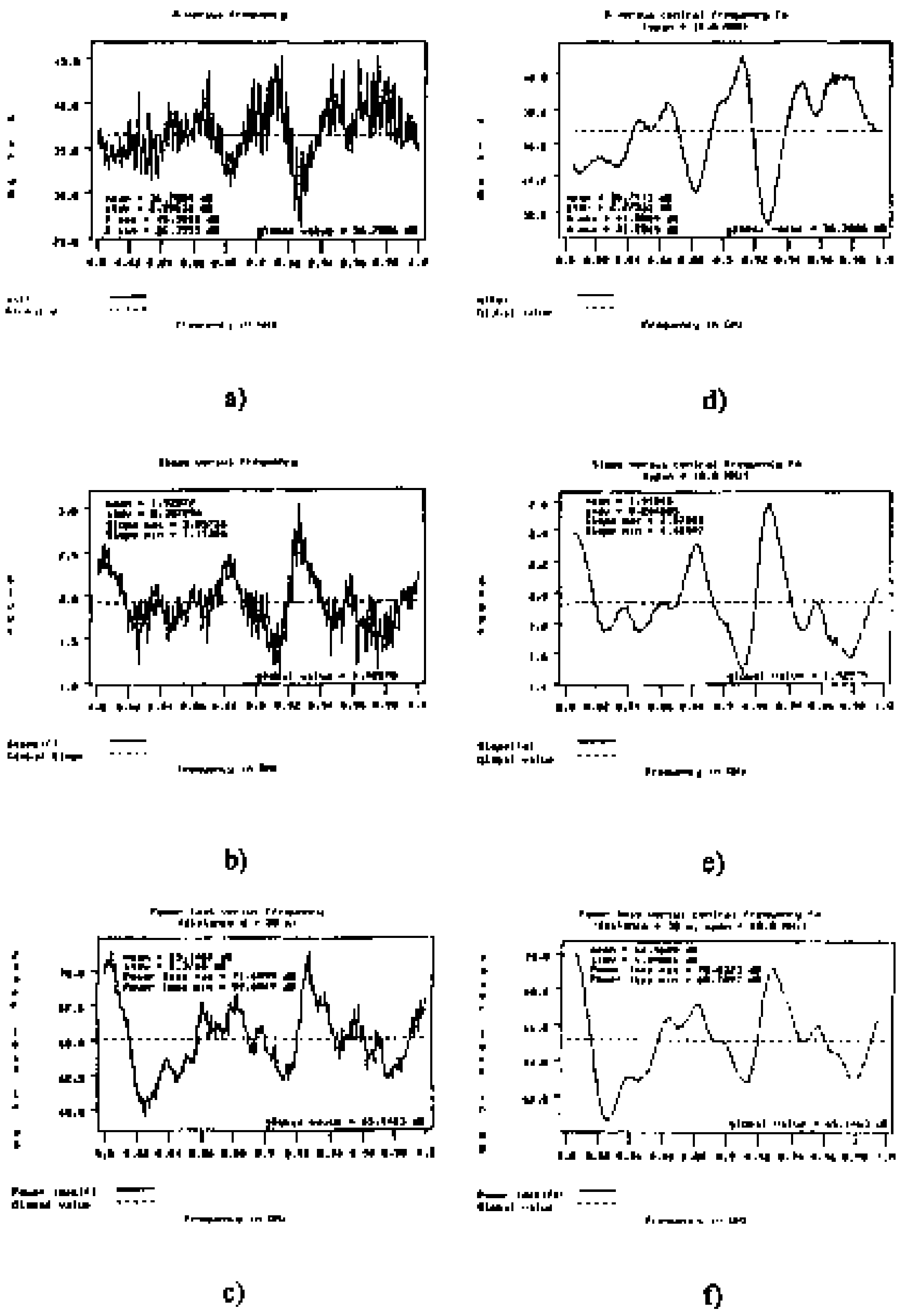

Fig.1. a),b) and c): method B; d),e) and f): method C.

results. Now, the linear regression analysis can be performed for each frequency. From this analysis, 801 values for A and α are obtained. Fig.1 a) and b) show a plot of A(f) and α(f) versus frequency. The global values obtained above are also shown. Some important conclusions can be pointed out:

1) the channel presents a considerable frequency selectivity;

2) the averages of the 801 samples for A(f) and α(f) respectively are equal to the global values obtained above (this observation may be

mathematically proved). Therefore, this analysis is more general: the results obtained at paragraph A. may be deduced from paragraph B. by simple averaging;

3) using $A(f)$ and $\alpha(f)$, relation (6) allows the computation of the power loss in dB versus frequency for a fixed distance. Fig.1 c) shows a plot of the power loss versus frequence for d = 30 m.

It is obvious that this result is more useful: for f = 825 MHz (for exemple...), the power loss is P = 60 dB, since for f = 926 MHz, P = 72 dB. For a given communication system with a 10 MHz frequency band, it is more convenient to choose the band 825 MHz - 835 MHz than the band 925 MHz - 935 MHz. In other words, the radio coverage depends on the choosed band.

C. *Power loss versus distance for a given frequency band:* Assuming we have a communication system with a 10 MHz frequency band centered at f_0, the problem is to obtain the radio coverage, in other words to obtain a plot of the power loss versus f_0 for a given distance. For this exemple, we have 805 MHz $\leq f_0 \leq$ 995 MHz, so the band of the considered communication system is $b = [f_0 - 5\text{ MHz}, f_0 + 5\text{ MHz}]$. For a given f_0, we may use the first-type analysis: for the 41 power loss values contained in the frequency band b, the average value may be computed:

$$P(d) = \frac{1}{41}\sum_{i=1}^{41} P(f_i,d) \tag{7}$$

Then, the linear regression analysis between P(d) and d gives A and α for the frequency f_0. Using this regression analysis for all possible values of f_0, $A(f_0)$ and $\alpha(f_0)$ may be obtained. Fig.1.d) and e) show A and α versus f_0. In fact, the results represent a smoothing of the curves presented in Fig.1.a) and b). So, it is not necessary to repeat 761 times the regressive analysis.Then, using (6) for d = 30 m and $f = f_0$, the power loss may be obtained. The result shown in Fig.1.f) is a smoothing of the curve presented in Fig.1.c).

It seems that the results of the method C are more useful for practical applications.

CONCLUSION

This paper presents a simplified setup to measure wideband path loss of indoor radio channels. Two new postprocessing methods were described. Method B is the most general: it may be used to obtain the results of the other methods, in particular the results presented in Reference [1,2].

REFERENCES

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